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<p>(54) Title : LOW-PROFILE SYMES FOOT PROSTHESIS</p>		
<p>(57) Abstract</p> <p>A prosthetic foot (10, 100) is characterized by a low-profile, elongated forefoot portion (12, 112) incorporating an attachment section (22, 116), an arch section (26, 118) and a toe section (28, 120), said forefoot portion (12, 112) being configured so that the foot (10, 100) may be worn by Symes-type amputees. The foot (10, 100) further preferably includes a heel portion (14, 114) secured to the forefoot portion (12, 112). A preferably demountable connection (36, 126) of the heel portion (14, 114) to the forefoot portion (12, 112) permits interchangeability of those components to match the weight, stride and activity schedule of the wearer utilizing the prosthetic foot (10, 100). Adjustment means (134) is provided to permit adjustment and alignment of the foot (10, 100) with respect to the wearer's stump.</p>		

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LOW-PROFILE SYMES FOOT PROSTHESIS

Background of the Invention:

5        This invention relates to foot prostheses in general, and specifically to a prosthetic foot adapted for use by persons who have undergone what is known in the art as a Symes amputation. This amputation severs the foot from the leg near the ankle region. Because the Symes patient's calf  
10      and shin functions as the patient's stump for prosthetic purposes, any prosthetic device utilized by the patient must either be relatively compact so as to be attachable below the point of amputation, or must be configured to accommodate the patient's shin and calf while attached thereto or  
15      higher up on the wearer's leg.

      Prior art prostheses available to Symes patients typically include an artificial foot bonded or bolted onto the bottom end of a socket worn on the patient's stump. Examples of prior art Symes-type prostheses include U.S.  
20      Pat. No. 3,874,004 to May, which teaches an artificial ankle joint which can pivot in simulation of a natural ankle, and U.S. Pat. No. 4,225,982 to Cochrane, which teaches an elong-

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gated socket secured to a rubber-filled cavity of a slipper member.

Other prosthetic foot devices include U.S. Pat. No. 3,335,428 to Gajdos, which attempts to duplicate the skeletal and skin structure of a natural human foot, U.S. Pat. No. 2,075,583 to Lange, which incorporates a rubber form mounted in operative relationship with a rigid metallic core, and U.S. Pat. No. 4,645,509 to Poggi, which teaches a prosthetic foot incorporating a monolithic keel or beam of relatively massive proportions intended to react to the load of an amputee's body during walking, running, jumping, and the like and to release the resultant stored energy to create foot lift and thrust complementing the amputee's natural stride.

These and other prosthetic foot devices, however, have significant deficiencies; for example, the May '004 and the Cochrane '982 patents achieve relatively focused and limited stress response because of their structure and reliance on hardened rubber members for flexure. Moreover, the component parts of the prostheses are too heavy and too rigid, as in Lange, or are too massive and monolithic, as in Poggi, to respond properly to the nuances of stress-response gradients characteristic of the human foot.

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Certain of these performance deficiencies are overcome in U.S. Letters Patent No. 4,547,913 for my invention relating to a "Composite Prosthetic Foot and Leg", United States Letters Patent No. 4,822,363 for my invention 5 relating to a "Modular Composite Prosthetic Foot and Leg", and United States Letters Patent No. 5,037,444 for my invention relating to a "Prosthetic Foot". Also, my pending application Serial No. 07/337,374 discloses a prosthetic foot device with similar preferred materials and methods of manufacture, and with corresponding benefits therefrom.

10 Each of my aforementioned inventions is characterized by lightweight, elongated structures incorporating polymer impregnation of superimposed reinforcing laminae or fibers maintained in the desired configuration. Such 15 configurations and constructions provide the desirable characteristics of strength and flexibility in the prosthetic member, and achieve a simulation of the performance of natural feet which had previously not been attainable. Such prostheses may be provided in modular assemblies, 20 whereby the particular performance characteristics of a given prosthesis may be adapted and readily adjusted to meet the needs and activity level of the individual patient.

None of my prior inventions, however, is readily utilized by Symes amputees, because of the various con-

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straints set forth above. Among other things, my prior prosthetic inventions are not configured to accommodate affixation to a Symes-type stump, in that the prostheses are not compact enough to be attachable below the point of amputation, nor are they configured to accommodate the patient's shin and calf while attached thereto or higher up on the wearer's leg.

Objects and Advantages of the Invention:

10 It is, therefore, an object of my invention to provide a low-profile prosthetic foot suitable for use by Symes amputees, which foot incorporates the desirable lightweight, flexible, energy-absorbing and energy-storing performance of certain of my prior inventions.

15 It is a further object of my invention to provide a prosthetic foot of the aforementioned character which is of modular configuration, resulting in ready assembly and adjustability thereof. The foot of my invention preferably includes forefoot and heel portions that can be readily exchanged with correspondingly-constructed forefoot and heel portions to provide size adjustment or different spring rates to suit the size of foot of the amputee or the stride, height, weight, and activity level of the amputee. Therefore, a range of combinations of spring rate and size can be

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provided to the amputee, achieving a natural stride and resilience of gait, which has not been fully obtainable by prior art prosthetic devices.

5 In addition to bringing important benefits to Symes amputees, my invention may be utilized in connection with pylons by being operatively attached to the lower end thereof, and would thereby be useful to non-Symes amputees in certain applications.

10 The preferred embodiment of the invention is characterized by its low profile, which permits utilization by amputees having very low Symes amputations. Moreover, my invention provides means for adjustability for desired and necessary planarflexion and dorsiflexion of the foot.

15 It is a further object of my invention to provide a low-profile prosthetic foot which is characterized by a forefoot portion incorporating an attachment section and an arch section and a toe section extending forwardly therefrom, said attachment section being configured to be operatively positioned, retained and utilized below a wearer's 20 stump; and a heel portion having an attachment section secured to said forefoot portion and a heel section extending rearwardly therefrom. In a preferred embodiment, the heel portion is demountably attached to the forefoot portion

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to permit heel portions having different spring rates to be secured to said forefoot portion of said foot.

An additional object of my invention is to provide a lower leg prosthesis having an attachment means for 5 attaching the prosthesis below a wearer's stump, in combination with an elongated, substantially flat forefoot portion, said forefoot portion including an attachment section for operative alignment and retention of the prosthesis under the wearer's stump, and an arch section and a toe section 10 extending forwardly therefrom.

It is a further object of my invention to provide a prosthetic foot of the aforesaid character which is fabricated from superimposed laminates maintained in operative relationship by an encapsulating polymer and susceptible to 15 bending stress determined by the dimensions of the laminates, or from chopped fiber maintained in operative relationship by an encapsulating polymer and susceptible to bending stress determined by the cross-section of the respective heel and/or forefoot portions.

20 Yet another object of my invention is the provision of a prosthetic foot of the aforementioned character which may be utilized with one or more auxiliary support members to permit fine-tuning of the performance characteristics of the foot.

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Another object of my invention is the provision of a prosthetic foot of the aforementioned character having a forefoot portion of unitary structure which is continuous, integrally and simultaneously formed to provide spring 5 stress generated energy storage, whereby the subjection of said toe section to bending moments will cause uniform transmission of spring stress through said arch and said toe sections to said attachment section.

The polymers utilized to encapsulate the fibrous 10 laminae or chopped fiber are characterized by elasticity and flexibility so that the foot prosthesis deflects proportionally to the engagement of said prosthetic foot with an adjacent surface, causing the resultant energy to be stored and subsequently released when the gait of the amputee incorporating thrust and lift components results in the utilization 15 of the stored energy and a consequent reduction of the energy expended by the amputee.

In order to impart a cosmetic aspect to the prosthetic foot, after proper fitting of the foot to insure that 20 it is properly balanced and of appropriate size, the prosthesis may be encapsulated in a suitably shaped cosmetic shroud. The shroud must be sufficiently flexible so as not to inhibit the free movement and flexure of the foot, but, because of the inherently resilient and stress-absorbing

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characteristics of said foot, little dependence is needed upon the ancillary cushioning action of the shroud.

Consequently, the foot of my invention is characterized by extreme light weight, instantaneous response to 5 imposed loads and correspondingly instantaneous delivery of stored energy when the gait of the wearer indicates that such stored energy is to be released. The wearer of the foot may engage in a wide variety of activities which were precluded in the past, or in activities in which the 10 wearer's enjoyment was limited, because of the structural limitations and corresponding performance of prior art prostheses. Running, jumping and other activities are sustained by the foot and it may be utilized in substantially the same manner as the normal foot of the wearer.

15 Another object of my invention is to provide a prosthesis of the aforementioned character that may be completely or substantially disposed within the patient's shoe, thus providing an optimum cosmetic appearance.

An additional object of my invention is the provision of a prosthetic foot of the aforementioned character in 20 which the aforescribed forefoot and heel portions may be manufactured by various expedients, including injection molding and/or the use of thermoplastic materials and processes, or any of a range of combinations thereof.

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Other objects and advantages of the invention will be apparent from the following specification and the accompanying drawings, which are for the purpose of illustration only.

5        Brief Description of the Drawings:

FIG. 1 is a front elevation view of an alternative embodiment of a prosthesis constructed in accordance with the teachings of the invention;

10        FIG. 2 is a plan view of an alternative embodiment of a prosthesis constructed in accordance with the teachings of the invention;

FIG. 3 is a side elevation view, taken along line 3-3 of FIG. 2;

15        FIG. 4 is a side elevation sectional view, taken along line 4-4 of FIG. 2;

FIG. 5 is a partially sectional side elevation view of an alternative embodiment of the prosthesis of the invention, similar to the view shown in FIG. 3;

20        FIG. 6 is a side elevation view of yet another embodiment of the invention, similar to the view of FIG. 3;

FIG. 7 is a side elevation, partially sectional view of a preferred embodiment of the invention, similar to

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the view of FIG. 6 but incorporating an arcuate, adjustable attachment structure;

FIG. 8 is a sectional view of the prosthesis of FIG. 7, illustrating flexure of the forefoot portion during, 5 for example, ambulation, and further illustrating the adjustment means positioned in a forward position as compared to FIG. 7;

FIG. 9 is a side elevation, partially sectional view of a preferred embodiment of the invention, illustrating 10 its utilization with a socket structure; and

FIG. 10 is a side elevation, partially sectional view of another embodiment of the invention, illustrating the use of an auxiliary support or spring means.

Description of Preferred Embodiment:

15 The preferred embodiment of my invention is illustrated in FIGS. 7-9, as more fully described herein, but many of the basic fabrication techniques and principles of operation of my invention are similar for the embodiments set forth in FIGS. 1-5. Those fabrication techniques and 20 principles of operation are described in some detail in my co-pending application, Ser. No. 07/585,920, and are briefly reviewed here.

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Generally, the embodiments of FIGS. 1-5 include a foot prosthesis 10, FIG. 3, which includes a forefoot portion 12 and a heel portion 14 secured thereto. The forefoot portion 12 preferably includes an attachment section 22, a 5 curvilinear ankle section 24, an arch section 26 and a toe section 28. The heel portion 14 preferably includes an attachment section 32 and a heel section 34 projecting rearwardly therefrom. The various sections of the forefoot and heel portions, respectively, are preferably formed integrally with one another and simultaneously by the incorporation of a plurality of laminae 16, FIG. 4, embedded in a hardened, flexible polymer, similar to the fabrication methods taught in my above-noted patents.

Although the ankle section 24 of the forefoot portion 12, as best shown in FIGS. 3-5, is configured to permit juxtaposition thereof to a rearward surface 66 and a lower surface 68 of a socket associated with the wearer's stump, the preferred embodiment of my instant invention, FIGS. 7-9, provides a prosthetic foot with an even lower profile, 15 thereby making it more useable by persons with even lower amputations or providing an alternative to the configurations of FIGS. 1-5. Moreover, the embodiment of FIGS. 7-9 may be readily adapted for use in connection with a wide 20 variety of other prosthetic devices such as, for example,

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being mounted on the lower end of a known prosthetic pylon tube (not shown).

Referring to the drawings, and particularly to FIG. 7 thereof, I show a foot prosthesis 100 constructed in 5 accordance with the teachings of the invention and including a forefoot portion 112 and a heel portion 114 secured thereto.

The forefoot and heel portions of my invention, as well as the inventions of my above-noted patents, may be 10 manufactured by any of a variety of expedients, including injection molding, resin-impregnation of laminates, the use of thermoplastic or thermoset materials and processes, or any of a range of combinations thereof.

Among other things, chopped fiber may be blended 15 in a thermoplastic or thermoset resin and the resulting mixture injection molded into an appropriate configuration. Alternatively or additionally, thermoplastic laminae may be wound around an injection-molded core, or a thermoplastic resin may be injected between thermoplastic or thermoset 20 laminae, whereby the laminates are bonded onto the injected material.

The forefoot portion 112 preferably includes an attachment section 116, and an arch section 118 and a toe section 120 extending forwardly thereof. In order to pro-

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vide the desired energy transmission characteristics of my invention, these sections are preferably formed integrally and simultaneously with each other, and may include laminates extending through the entire length of the forefoot portion 112. The forefoot portion (as well as the heel portion 114) may be tapered or altered in cross-section along its length, in order to modify the energy-storage and release performance of the prosthesis. The fibers or laminates imbedded in the prosthesis may also be fayed or tapered to assist in or accomplish the same result.

The heel portion 114 preferably includes an attachment section 122 and a heel section 124 extending rearwardly therefrom. In the preferred embodiment, the heel portion 114 is demountably attached to the forefoot portion through the use of nut, washer and bolt combinations 126 or similar expedient, although permanent attachment of the heel through the use of epoxy, resin, or simultaneous forming may be utilized with efficacy. Demountable attachment is preferred, in that it permits the forefoot portion 112 to be selectively affixed to any of various heel portions 114 having different spring rates.

Pad members 128 may be affixed to the underside of the forefoot and heel portions, to create a profile for the bottom of the prosthesis 100 which corresponds to the inte-

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rior of a shoe. Such a profile orients the foot 100, when the foot is in an unstressed state, at an appropriate angle for wearing shoes.

As illustrated in FIGS. 7 and 8, the preferred 5 embodiment of my invention is utilized in connection with an attachment plate member 130. The plate member 130 preferably provides a curvilinear contact surface adjacent the attachment section 116, and is adapted to be incorporated into a socket 132, FIG. 9, or otherwise operatively attachable to a wearer's stump. The aforesaid incorporation into 10 a socket 132 may be achieved through simultaneous formation of the socket 132 and the plate member 130, subsequent lamination or adhesion therebetween, or other expedient.

Further in the preferred embodiment, the attachment plate member 130 is operatively attached to the attachment section 116 through the provision of attachment and 15 adjustment means 134 such as nut, washer and bolt combinations 136 or similar expedient. The adjustment means 134 further preferably includes mounting slots or holes 138 in 20 the attachment section 116, which are elongated or otherwise of large enough dimension to permit the nut and bolt combinations 136 to be selectively positioned therein.

Those skilled in the art will understand that alternative embodiments of the invention include permanent

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affixation of the plate member 130 to the attachment section 116, or even direct formation or incorporation of the attachment section 116 into the socket 132. They will also understand, however, that the preferred embodiment of FIGS. 5 7-9 provides a beneficial adjustability and individual customization of the prosthetic foot which would not be achievable in such alternative constructions.

10 Specifically, the aforesaid selective positioning of the nut and bolt combinations 136 in the mounting slots or holes 138 permits rotating attitude adjustment and alignment of the prosthesis to accommodate an individual wearer's needs. The upper surface of the attachment section 116 may be radiused to correspond to the shape of the attachment plate 130 for this same purpose. In prototypes, this curvature has been utilized to permit an attitude adjustment of 15 up to eight (8) degrees within a single prototype.

20 As shown in FIG. 8, the preferred assembly permits sliding movement of the plate 130 with respect to the attachment section 116, to and fro in the direction indicated by the arrow A. When a desired position is selected, the attachment means 134 may be appropriately tightened to provide frictional, non-sliding contact between the plate 130 and the attachment section 116.

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The abovedescribed incorporation of the attachment plate member 130 into the socket 132, through lamination or otherwise, is preferably accomplished so that the just-described adjustability of the attachment means 134 is neither precluded nor interfered with. In short, the resulting socket 132 preferably has an outer profile which is configured to cooperate with its mating upper surface of the attachment section 116 in the manner described above.

The prosthesis of my invention further preferably includes cavity means 140 such as one or more cavities 142 correspondingly configured and positioned to receive any projecting portion of the adjustment means 134 during ambulation of said foot. Such ambulation and loaded condition of the prosthesis is illustrated in FIG. 8, showing the reception of the nut and bolt means 136 in the cavity 142. This cooperative relationship permits the attachment section 116 to be flexed downwardly, as shown by arrow B, FIG. 8, further than would be possible without the provision of the cavity 142. Such additional degree of flexure provides a corresponding additional degree of energy storage and release and improved performance of the prosthesis.

FIG. 6 illustrates an alternative embodiment of my invention. The heel portion 14 and the arch section 26 and toe section 28 of the forefoot portion 12 of FIG. 6 are also

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substantially the same as those illustrated in FIGS. 1-5. The embodiment of FIG. 6 differs from those of FIGS. 1-5, however, in that an attachment section 70, similar to attachment section 116 of FIGS. 7-9, is formed adjacent to and integrally with the arch section 26; the curvilinear ankle section 24 of FIG. 3 is not present in the embodiment of FIG. 6. Attachment means such as an attachment plate 72 and corresponding screws 74, FIG. 6, are provided adjacent to the attachment section 70 to provide affixation to the wearer's socket, similar to socket 132 of FIG. 9.

The structure and method of this attachment may include, for example, any of those described in my copending application regarding attachment means 40 of FIGS. 1-4 or socket member 50 of FIG. 5. As indicated in FIG. 6, however, the front edge 76 of the attachment plate 72 is preferably provided with a curvilinear surface to reduce stress concentration in that area during flexure of the prosthesis.

As an alternative to the nut and bolt combinations 136 of FIGS. 7-9, in order to maximize the amount of flexure available with the prosthesis of FIG. 6, button-head screws 74 or other low-profile attachment means are preferred. As indicated above, higher profile attachment means have the disadvantage of contacting the heel section 34, FIG. 6, dur-

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ing heavy loading, thus preventing desired further flexure of the components of the prosthesis.

As indicated above, the forefoot and heel portions 112 and 114 are preferably fabricated from superimposed 5 laminates such as laminates 16, FIG. 4, maintained in operative relationship by an encapsulating polymer and susceptible to bending stress determined by the thickness of the laminates. The preferred materials and fabrication process are more thoroughly described and explained in my above- 10 mentioned U.S. Patent Nos. 4,547,913, 4,822,363, and 5,037,444 and include laminates such as carbon fibers and/or fiberglass or synthetic fibers such as Kevlar. Exemplary alternative methods and materials are described hereinabove.

The construction of the forefoot and heel portions 112 and 114 of my invention thus preferably includes 15 continuous, integrally and simultaneously formed sections 116, 118, and 120, and 122 and 124, respectively. The aforesaid sections are fabricated as unitary structures by polymer impregnation of the aforescribed superimposed 20 reinforcing laminae. As a result of the materials, design and construction of the prosthetic foot 10, the various sections are capable of spring stress generated energy storage whereby the subjection of the prosthetic foot of my inven-

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tion to bending moments or other stress loading will cause transmission of spring stress through said sections.

It will be obvious to those skilled in the art that a virtually infinite variety of forefoot portions 112 and heel portions 114 may be fabricated, each having unique spring stress response characteristics determined by the configuration, composition and amount of the various component materials utilized therein. The aforementioned demountable connection of the heel portion to the forefoot portion therefore permits interchangeability of those portions to match the weight, stride and activity schedule of the wearer utilizing the prosthetic foot.

The foot 100 may be affixed to the wearer by any of several means. As described above, a socket 132 may be affixed directly to the foot 100. Alternatively, a tubular pylon (not shown) may be attached to the foot through the use of epoxy, glue, brackets or the like. For amputees who may utilize tubular pylons, however, a greater degree of energy storage and release may be provided by certain of my other aforementioned inventions.

The attachment section 116, when assembled with the attachment means 134, is substantially rigid and capable of sustaining torsional, impact, and other loads impressed thereupon by the wearer during use of the foot 100. In

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addition, the inherent rigidity of the attachment section prevents it from being distorted in any way and causes the effective transmission of the aforesaid loads imposed there-upon between the wearer and the prosthetic foot 100.

5 A cosmetic shroud similar to the shroud 64, FIG. 5, may be utilized to encapsulate the foot 10, in a manner more fully explained in my previously-described patents.

In addition to the foregoing, those skilled in the art will understand that auxiliary support or spring means 144 such as flexure members 146, FIG. 10, may be efficaciously utilized in connection with any embodiment of the above-described invention, without departing from the scope of the teachings hereof. Although a broad variety of auxiliary spring means 144 may be utilized with efficacy, 10 including a range of configurations and sizes and locations on the prosthesis 100, the embodiment of FIG. 10 is illustrative.

In FIG. 10, the auxiliary support member 146 is configured similarly to the forefoot portion 112. Nut and 20 bolt combinations 126 and 136, or similar expedient, are utilized to retain the various components in operative alignment. In order to permit the desired flexure of each of members 112 and 146 independently from each other, an oversized opening such as opening 148 is preferably provided

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in either or both of members 112 and 146. This ensures that, if the members are fixed with respect to each other at a location, for example, such as the attachment section 116, the remainder of the members 112 and 146 may slide with 5 respect to each other when deformation of the prosthesis occurs (during ambulation or the like).

As indicated above, those skilled in the art will understand that the auxiliary support members may be provided by a wide variety of configurations, positioned to 10 cooperatively function with the rest of the prosthesis 100. Such auxiliary support members may be attached at various locations and in various manners on the prosthesis 100 without departing from the scope of the invention.

Among other things, these auxiliary support members 15 permit the energy-storage and -release characteristics of the foot 100 to be refined and fine-tuned. In that regard, the auxiliary support members 146 are preferably constructed from materials, and fabricated by techniques, similar to those from which and by which the other components 20 of the foot 100 are constructed and fabricated.

An important aspect of the polymers and laminates referred to hereinabove is that they are characterized by needed, but not excessive, flexural deflection under load, which characteristic permits the shock-absorption stress

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loading of the prosthesis 100 while maintaining sufficient stability to prevent the collapse of the prosthesis while loads are imposed thereupon.

To achieve the relatively thin construction of the 5 forefoot and heel portions 12 and 14, the aforesaid polymers are preferably utilized in conjunction with various fibers and/or laminating materials.

There is a wide variety of fibrous reinforcements available at the present time, including such inorganic 10 fibers as glass or carbon fibers.

The prosthetic foot of my invention can thus be provided in different sizes to correspond to the size of the natural foot of the wearer of the prosthesis 100. When such different sizes are provided, corresponding reduction or 15 increase in the cross-section and/or the number of laminae and thickness of taper, if any, of the respective sections of the forefoot and heel portions 112 and 114 can be made to provide for the proper flexure of said sections.

Moreover, and as mentioned above, the flexibility 20 of the prosthetic foot of my invention may be further increased, while still maintaining acceptable strength characteristics, by providing an auxiliary support member or auxiliary forefoot portion such as auxiliary means 144, FIG. 10. Such an auxiliary member or portion is preferably

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operatively positioned with respect to the forefoot portion 112 to provide the desired support while permitting some relative movement therebetween, thereby permitting the desired flexure.

5 By such a construction, the same total thickness of supportive material is achieved in an assembly of overlying, juxtaposed, thin layers, which construction has much more flexibility than does a unitary forefoot portion of the same total material thickness. Such an auxiliary support  
10 member can be especially beneficial in the construction of FIG. 6-9.

15 The aforementioned flexure of the foot portions 112 and 114 provides the capacity for increased surface area contact between the bottom surfaces of the foot 100 and the adjacent surface, during both the energy impact and delivery phases of the prosthesis 100. It will be noted that the elongated structure of the portions 112 and 114, together with their aforesaid flexure capabilities, provides for a relatively extended lever arm which achieves stress storage  
20 and stress reaction.

The preferred method of manufacturing the forefoot and heel portions 112 and 114 of the prosthesis 100 is by a thermosetting molding process including the utilization of molds having properly shaped and sized cavities. The cavi-

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ties are designed to receive the requisite number of laminates or fibers and the proper volume of polymer, such that the portions 12 and 14 are respectively unitary structures, with the various sections thereof formed simultaneously  
5 within each respective portion.

Unlike prior art unitary devices, the fitting of the prosthesis 100 involves the judicious adjustment of the prosthesis by the proper combination of forefoot and heel portions 112 and 114. Only when the proper correlation has  
10 been accomplished, can the cosmetic shroud be installed upon the assembled, respective portions of the prosthesis 100.

By the prosthesis of my invention I provide a foot prosthesis which can be carefully matched to the weight, stride and physical characteristics of the wearer. This is  
15 accomplished by carefully balancing the respective physical characteristics of the forefoot and heel portions 112 and 114 and the various sections thereof.

Moreover, the assembled prosthesis is far lighter in weight than prior art prostheses since the inherent design and structure of the prosthesis, the materials used and  
20 the careful calculation of stress factors of the components of the prosthesis permit fine-tuning of the prosthesis to the needs of the wearer thereof.

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The prosthesis of my invention has been described with some particularity but the specific designs and constructions disclosed are not to be taken as delimiting of the invention in that various obvious modifications will at 5 once make themselves apparent to those of ordinary skill in the art, all of which will not depart from the essence of the invention and all such changes and modifications are intended to be encompassed within the appended claims.

Claims:

## I CLAIM:

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1. In a low-profile prosthetic foot, the combination of: a forefoot portion incorporating an attachment section and an arch section and a toe section extending forwardly therefrom, said attachment section being configured to be operatively positioned, retained and utilized below a wearer's stump; and a heel portion having an attachment section secured to said forefoot portion and a heel section extending rearwardly therefrom.

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2. The prosthetic foot of Claim 1 in which said heel portion is demountably attached to said forefoot portion to permit heel portions having different spring rates to be secured to said forefoot portion of said foot.

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3. The prosthetic foot of Claim 1 or Claim 2 in which said heel portion and/or said forefoot portion is fabricated from superimposed laminates maintained in operative

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relationship by an encapsulating polymer and susceptible to bending stress determined by the thickness of the laminates.

4. The prosthetic foot of Claim 1 or Claim 2 in  
5 which said heel portion and/or forefoot portion is fabri-  
cated from chopped fiber maintained in operative relation-  
ship by an encapsulating polymer and susceptible to bending  
stress determined by the cross-section of the respective  
heel and/or forefoot portions.

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5. The prosthetic foot of Claim 1 or Claim 2,  
further including an auxiliary support member operatively  
associated with said forefoot portion.

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6. The prosthetic foot of Claim 1 or Claim 2,  
including adjustment means associated with said forefoot  
portion attachment section to permit attitude adjustment and  
alignment of the prosthesis with respect to a wearer's  
stump.

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7. The prosthetic foot of Claim 6, further  
including cavity means correspondingly configured and posi-  
tioned to receive a projecting portion of said adjustment  
means during ambulation of said foot.

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8. The prosthetic foot of Claim 6, in which said adjustment means constitutes one or more nut-and-bolt combinations, said bolts being operatively positioned through 5 openings in said attachment section of said forefoot portion.

9. In a lower leg prosthesis having an attachment means for attaching the prosthesis below a wearer's stump, 10 the combination with said prosthesis of an elongated, substantially flat forefoot portion, said forefoot portion including an attachment section for operative alignment and retention of the prosthesis under the wearer's stump, and an arch section and a toe section extending forwardly therefrom. 15

10. The prosthesis of Claim 9, in which said attachment section, said arch section, and said toe section are integrally fabricated to provide spring stress generated 20 energy storage whereby the subjection of said toe section to bending moments will cause uniform transmission of spring stress through said arch and said toe sections to said attachment section.

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11. The prosthesis of Claim 9 or Claim 10, further including a heel portion operatively attached to said forefoot portion.

5 12. The prosthesis of Claim 11, in which said heel portion is demountably attached to said forefoot portion.

10 13. The prosthesis of Claim 9 or Claim 10, further including an auxiliary ankle member secured to said forefoot portion.

15 14. In a prosthetic foot suitable for use by low-level Symes amputees, the combination of: an elongated forefoot portion consisting of continuous, integrally and simultaneously formed attachment, arch and toe sections; said attachment, ankle, arch and toe sections being capable of spring stress generated energy storage whereby the subjection of said foot to bending moments will cause transmission of spring stress through said attachment, arch and toe sections; said attachment section configured to permit juxtaposition thereof with a lower surface of a wearer's stump; and a heel portion having an attachment section for attach-

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ment to said forefoot portion and a heel section extending rearwardly therefrom.

15. The prosthetic foot of Claim 14 in which said  
5 heel portion consists of continuous, integrally and simulta-  
neously formed attachment and heel sections; said attachment  
and heel sections being capable of spring stress generated  
energy storage whereby the subjection of said foot to bend-  
ing moments will cause transmission of spring stress through  
10 said attachment and heel sections.

16. The prosthetic foot of Claim 14 or Claim 15  
in which said heel portion is demountably attached to said  
forefoot portion to permit heel portions having different  
15 spring rates to be secured to said forefoot portion of said  
foot.

17. The prosthetic foot of Claim 14 or Claim 15,  
further including an auxiliary support member operatively  
20 associated with said forefoot portion.

18. The prosthetic foot of Claim 14 or Claim 15,  
including adjustment means associated with said forefoot  
portion attachment section to permit rotating attitude

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adjustment and alignment of the prosthesis with respect to a wearer's stump.

19. The prosthetic foot of Claim 18, further including cavity means correspondingly configured and positioned to receive a projecting portion of said adjustment means during ambulation of said foot.

20. The prosthetic foot of Claim 18, in which said adjustment means constitutes one or more nut-and-bolt combinations, said bolts being operatively positioned through openings in said attachment section of said forefoot portion.

21. In a prosthetic foot, the combination of: an elongated forefoot portion incorporating an attachment section, and an arch section and a toe section extending forwardly therefrom, said attachment section being configured to permit juxtaposition thereof to a lower surface of a wearer's stump which has been amputated at or near the wearer's ankle region; and a heel portion having an attachment section secured to the intersection of said arch and toe sections and a heel section extending rearwardly therefrom.

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22. The prosthetic foot of Claim 21 in which said heel portion is demountably attached to said forefoot portion to permit heel portions having different spring rates 5 to be secured to said forefoot portion of said foot.

23. The prosthetic foot of Claim 21 or Claim 22, further including an auxiliary support member operatively associated with said forefoot portion.

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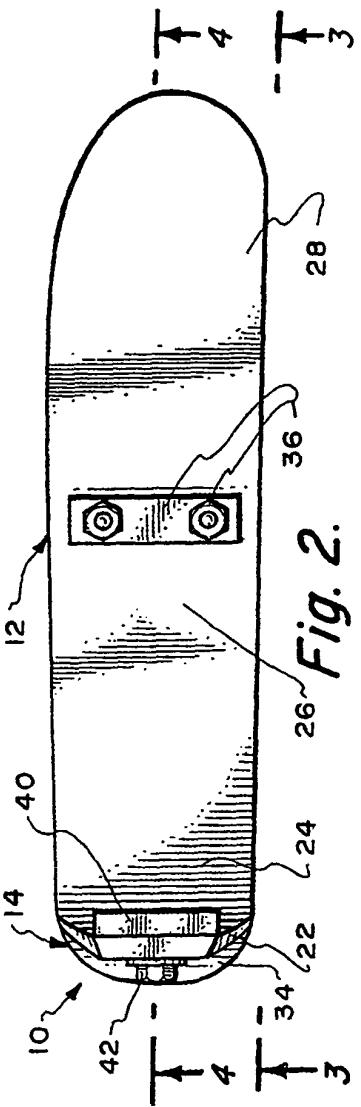


Fig. 1.

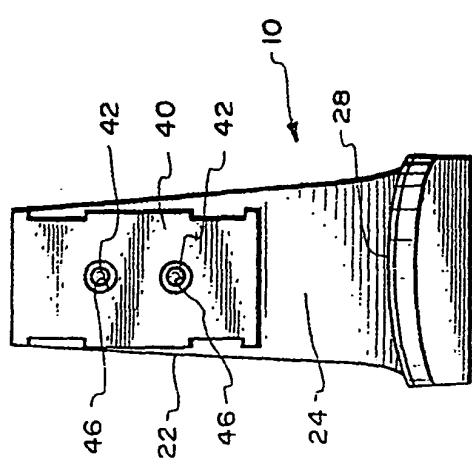


Fig. 2.

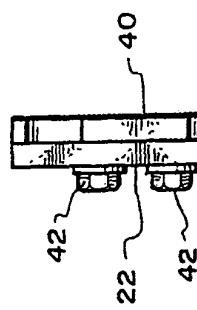


Fig. 3.

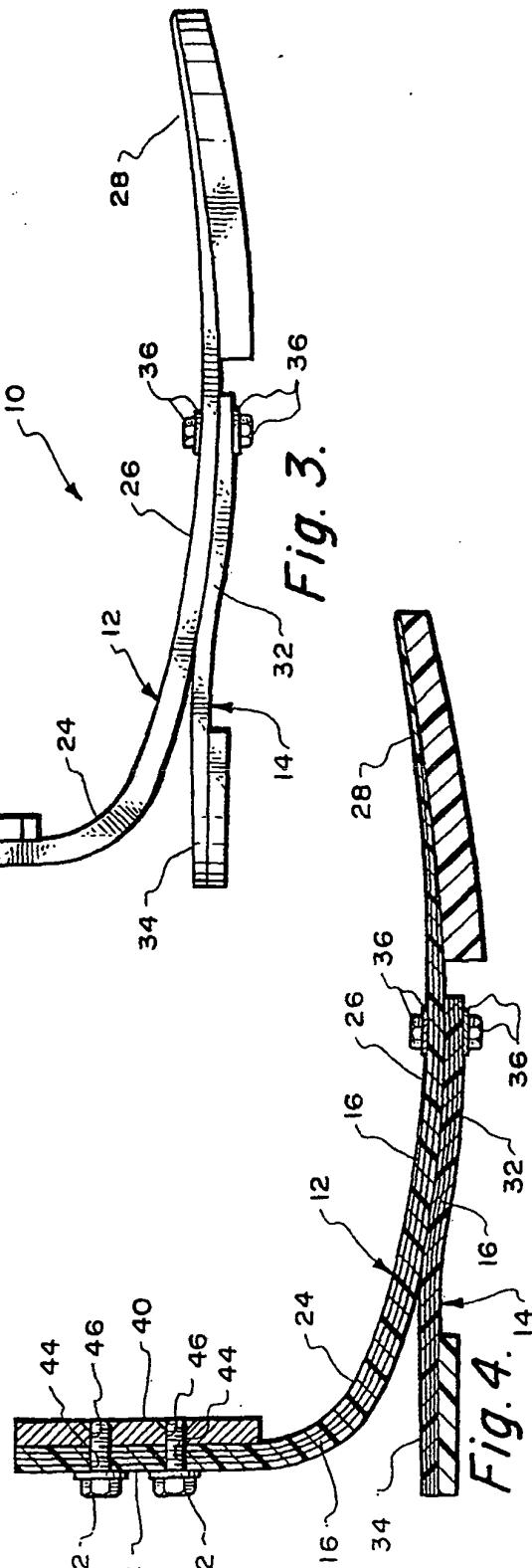
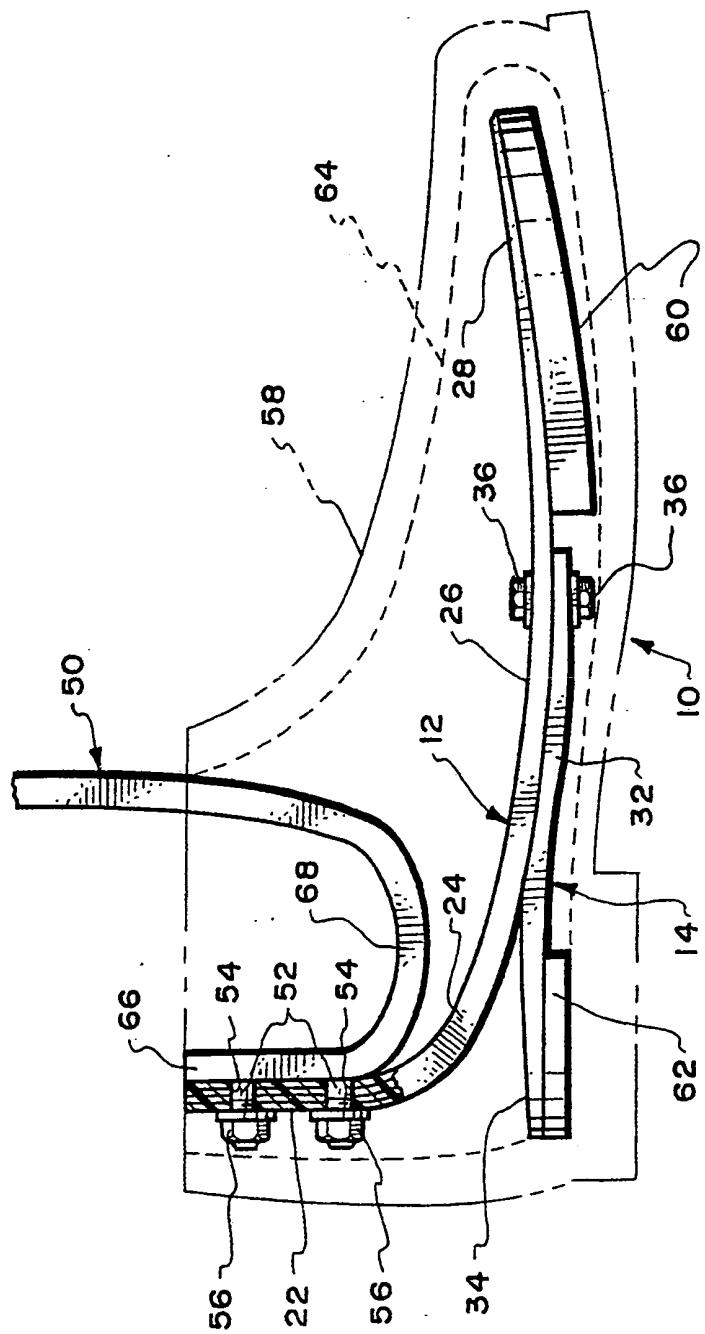
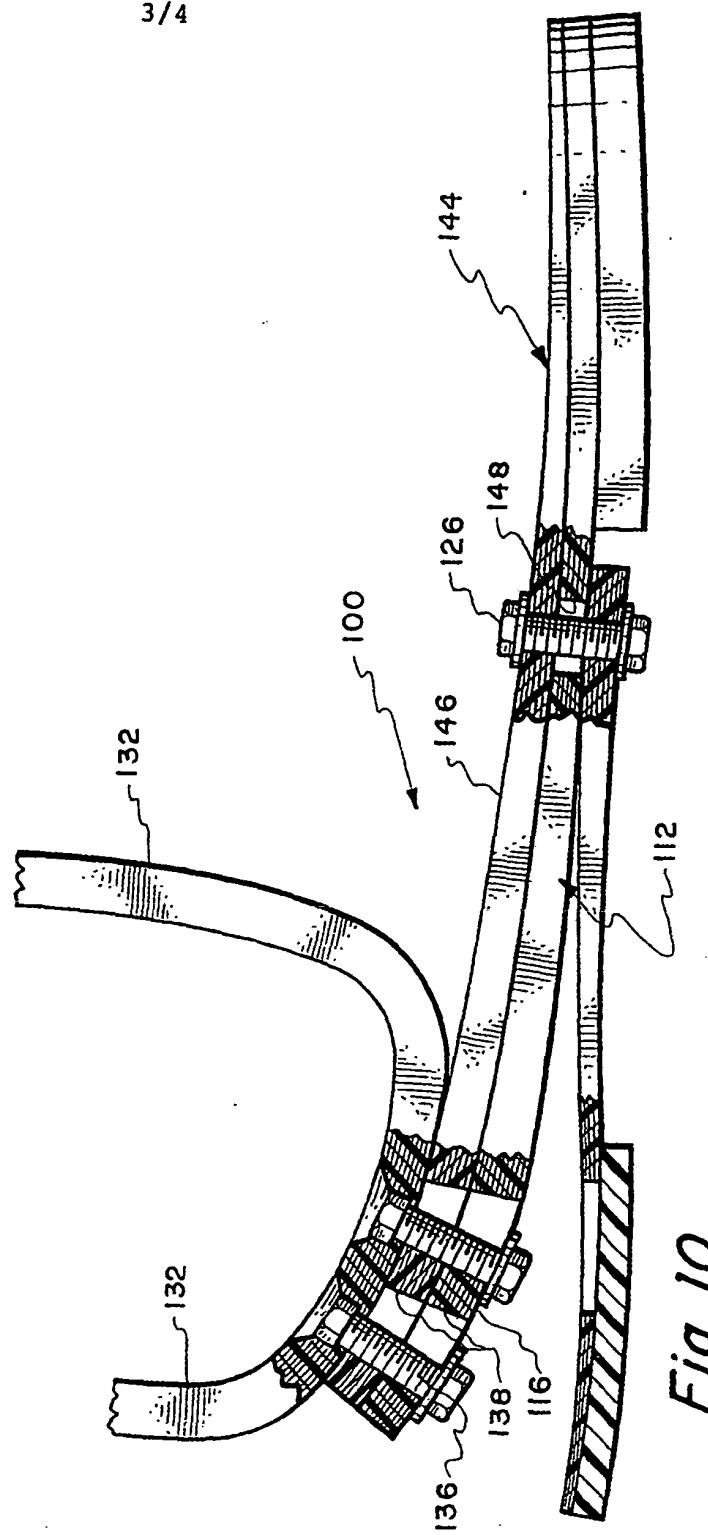
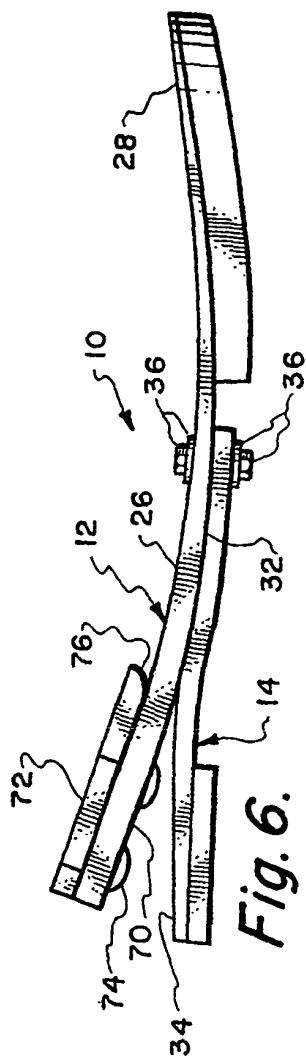


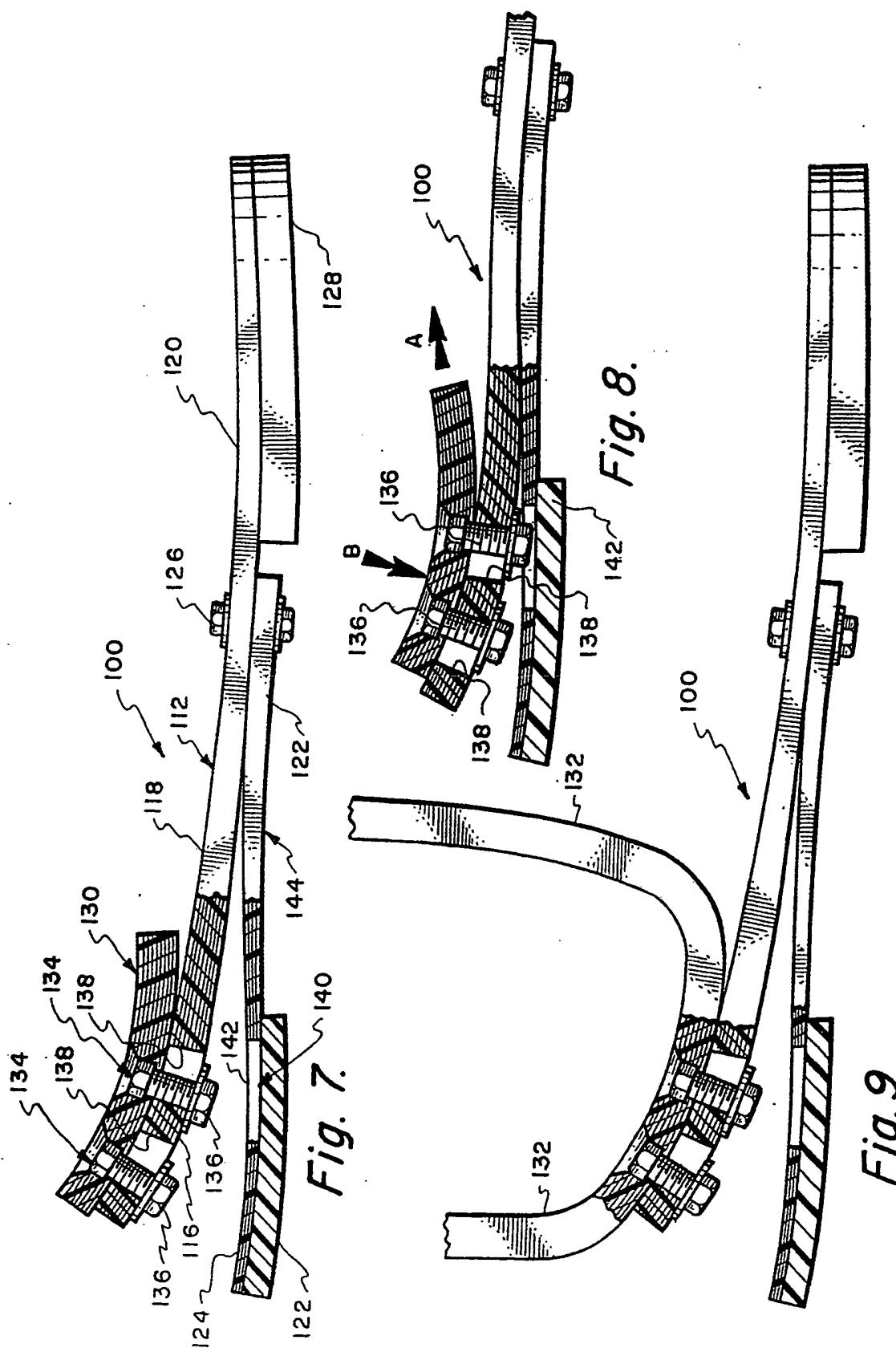
Fig. 4.



*Fig. 5.*

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## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 92/07438

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all)<sup>6</sup>

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 A61F2/66

## II. FIELDS SEARCHED

Minimum Documentation Searched<sup>7</sup>

Classification System	Classification Symbols
Int.Cl. 5	A61F

Documentation Searched other than Minimum Documentation  
to the Extent that such Documents are Included in the Fields Searched<sup>8</sup>III. DOCUMENTS CONSIDERED TO BE RELEVANT<sup>9</sup>

Category <sup>10</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
Y	US,A,5 037 444 (PHILLIPS) 6 August 1991	1-4, 9-12, 14-16, 21,22
A	see the whole document cited in the application ---	8,20
Y	US,A,4 225 982 (COCHRANE) 7 October 1980	1-4, 9-12, 14-16, 21,22
A	see column 2, line 33 - line 38; claims 1,5; figure 15 cited in the application ---	
A	WO,A,8 800 815 (T.O.W.W.C.) 11 February 1988 see page 6, line 10 - line 19 see page 8, line 4 - line 7; figures 1,6 ---	5,13,17, 23
		-/-

<sup>6</sup> Special categories of cited documents : 10<sup>7</sup> "A" document defining the general state of the art which is not considered to be of particular relevance<sup>8</sup> "E" earlier document but published on or after the international filing date<sup>9</sup> "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)<sup>10</sup> "O" document referring to an oral disclosure, use, exhibition or other means<sup>11</sup> "P" document published prior to the international filing date but later than the priority date claimed<sup>12</sup> "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention<sup>13</sup> "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step<sup>14</sup> "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art<sup>15</sup> "S" document member of the same patent family

## IV. CERTIFICATION

Date of the Actual Completion of the International Search

08 JANUARY 1993

Date of Mailing of this International Search Report

20.01.93

International Searching Authority

EUROPEAN PATENT OFFICE

Signature of Authorized Officer

KLEIN C.

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
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A	EP,A,0 331 468 (CHAS. A. BLATCHFORD) 6 September 1989 see column 3, line 55 - line 59; figures 1,5,6 ----	6-8, 18-20
A	GB,A,2 202 448 (PHILLIPS) 28 September 1988 cited in the application ----	
A	US,A,4 645 509 (POGGI) 24 February 1987 cited in the application -----	

**ANNEX TO THE INTERNATIONAL SEARCH REPORT**  
**ON INTERNATIONAL PATENT APPLICATION NO. US 9207438**  
**SA 64609**

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information. 08/01/93

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